Searches for Extra Dimensions

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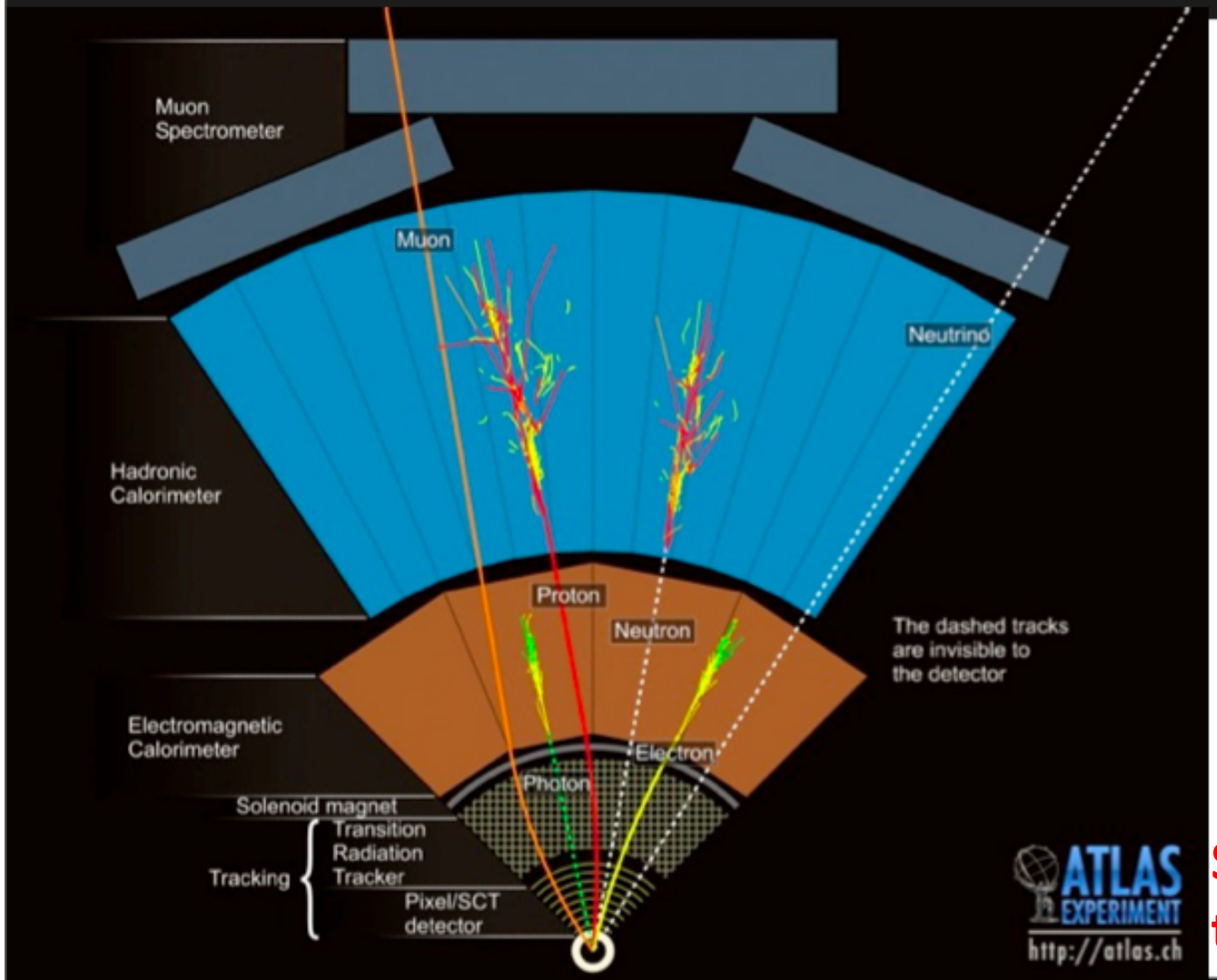
Outline

- Interesting Signatures
- ATLAS Detector – Very Brief
- Search for direct ADD G_{KK} Production
- Search for ttbar resonances from RS g_{KK}
- Conclusions

Signatures

- ADD:
  - $gg(q\bar{q}) \longrightarrow gG^{*}_{KK}$
  - Kaluza-Klein graviton doesn't interact in detector, giving Jet + MET signature
- RS:
  - $gg(q\bar{q}) \longrightarrow g^{*}_{KK} \longrightarrow t\bar{t}$
  - Focus on case where one top decays semi-leptonically
  - $gg(q\bar{q}) \longrightarrow G^{*}_{KK} \longrightarrow l^{+}l^{-}(\gamma\gamma)$

Identifying final state particles



Muon Detectors

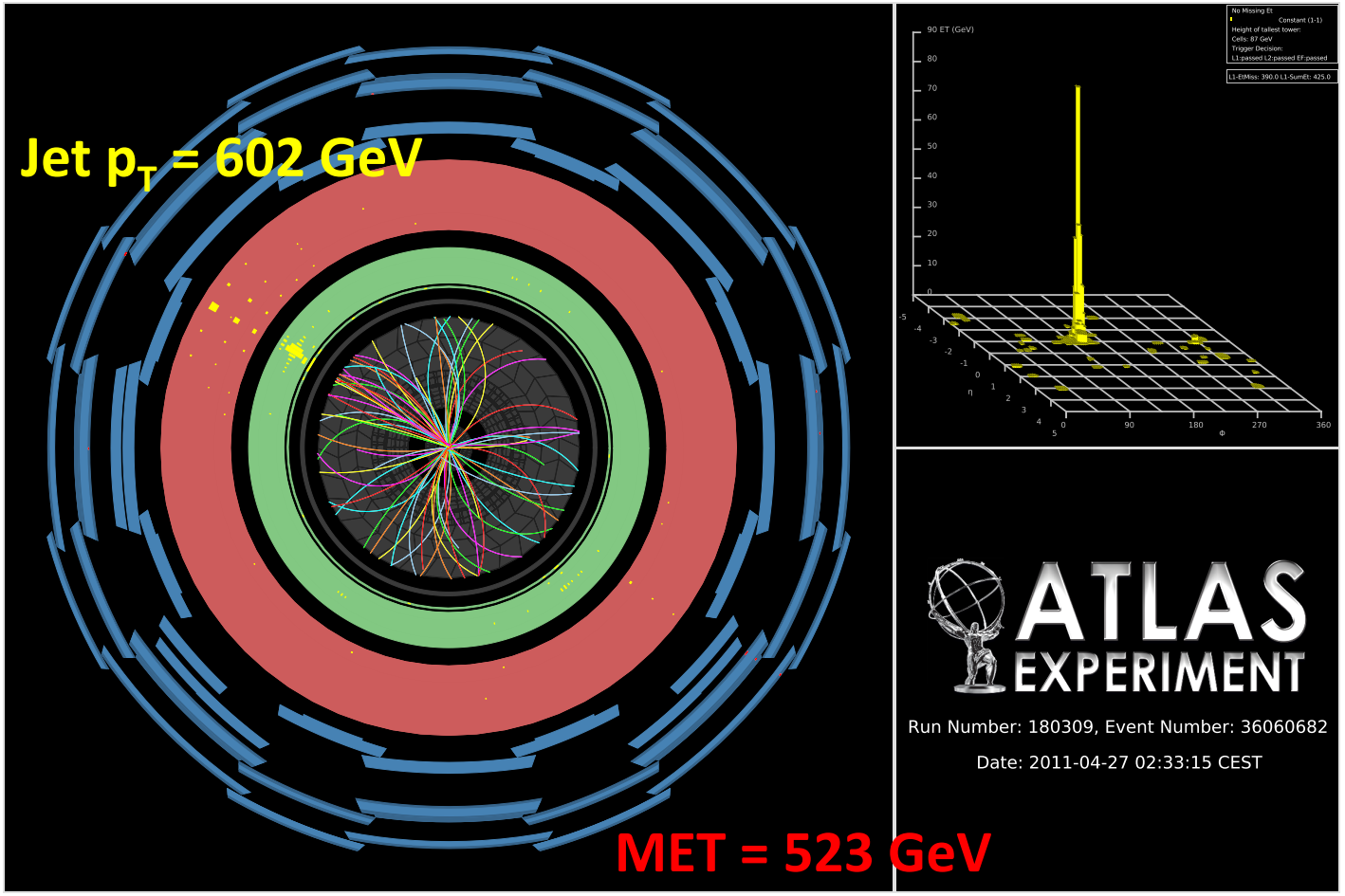
Calorimeters

Trackers

Stolen from Kathy's talk on Oct. 5th!

K. Copic 8

Monojet + MET



From ATLAS-CONF-2011-96

Backgrounds

- Dominant backgrounds are $Z(\rightarrow \upsilon\bar{\upsilon})$+jets and W+jets, where the lepton from the W decay escapes detection
- Additional collision background from DY+jets, QCD, $t\bar{t}$, and γ+jets, where misreconstruction of jets/leptons gives fake MET
- Non-collision background from cosmics, beam halo

Event Selection

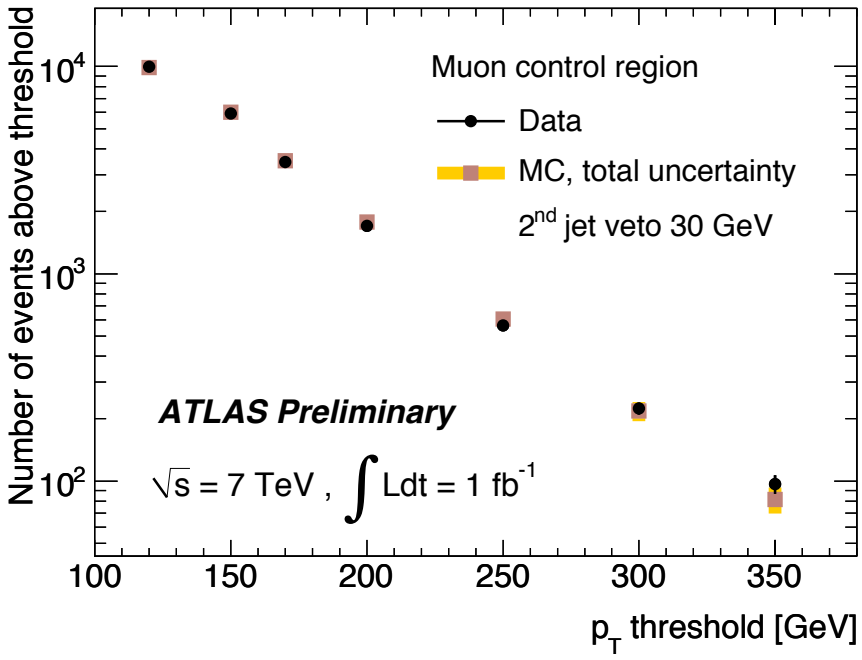
- Jets reconstructed using anti-k_T algorithm with cone size of 0.4
  - Jets within $\Delta R < 0.2$ of an electron are removed
  - Electrons with $0.2 < \Delta R < 0.4$ to any remaining jet are removed
- Veto events that contain
  - A medium electron with $p_T > 20$ GeV and $|\eta| < 2.47$
  - An isolated combined muon with $p_T > 10$ GeV and $|n| < 2.4$

Event Selection

- Three different channels: LowPt/HighPt/ veryHighPt require
  - One jet with p_T > **120**/**250**/**350** GeV and $|\eta| < 2$ and
  - MET > **120**/**220**/**300** GeV
  - Reject events with second jet with p_T > **30**/**60**/**60** GeV and $|\eta| < 4.5$
- For HighPt and veryHighPt channels, additional rejection of events with second jet within $\Delta\phi <$ 0.5 of MET and third jet with $p_T > 30$ GeV

EWK Background Estimation

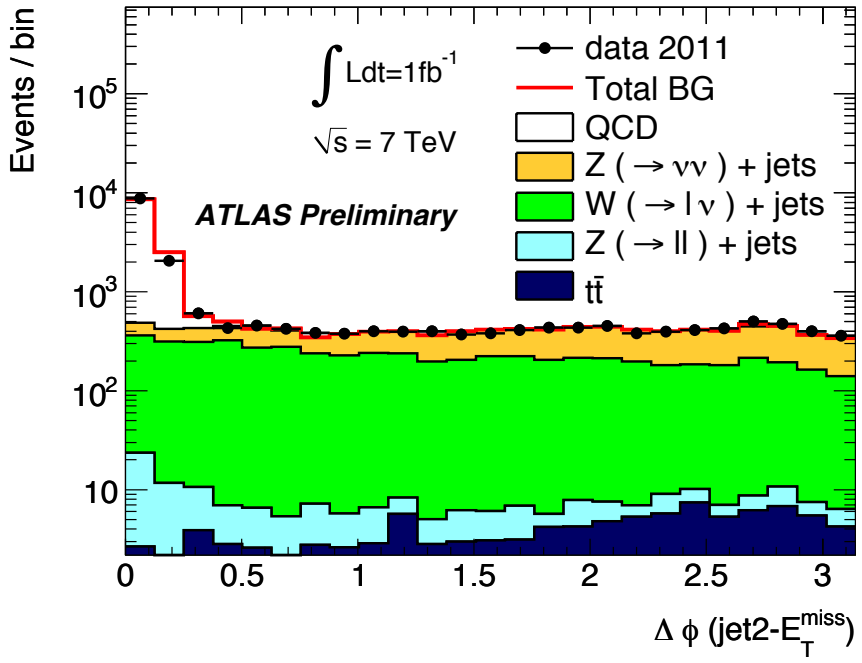
- Electroweak background estimated using MC normalized to data in control region with lepton veto reversed
- $t\bar{t}$ contribution to this region subtracted before normalization



Uncertainties on background predictions come from normalization (5-20%), lepton ID (4%) efficiency, and $t\bar{t}$ subtraction (2%).

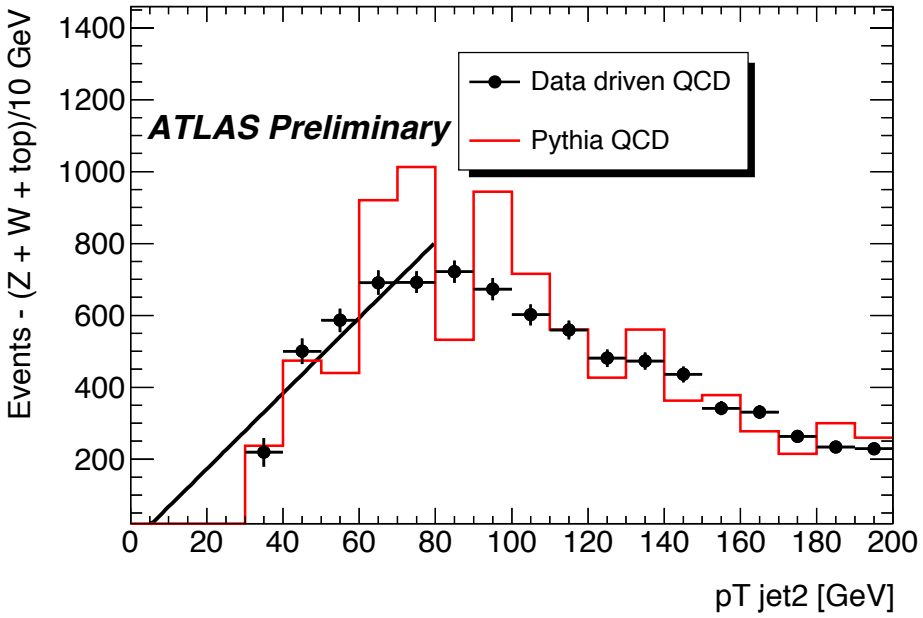
QCD Background Estimation

- QCD background estimated using data in control region cut on second leading jet p_T removed and $\Delta\phi$ cut reversed
- Contributions from other SM processes subtracted using MC estimates



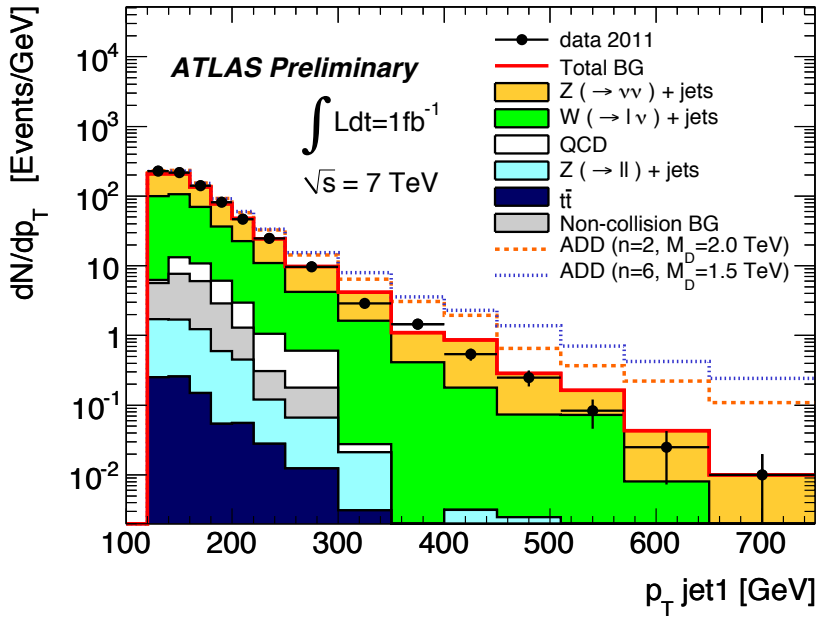
QCD Background Estimation

- Linear fit used to extrapolate to signal region
- Uncertainties on background prediction from fit and subtraction of other SM processes



Non-Collision Background Estimation

- Estimated by looking for events during empty bunches that are tagged by a beam-halo tagger
- Uncertainties from tagger efficiency and pileup effects

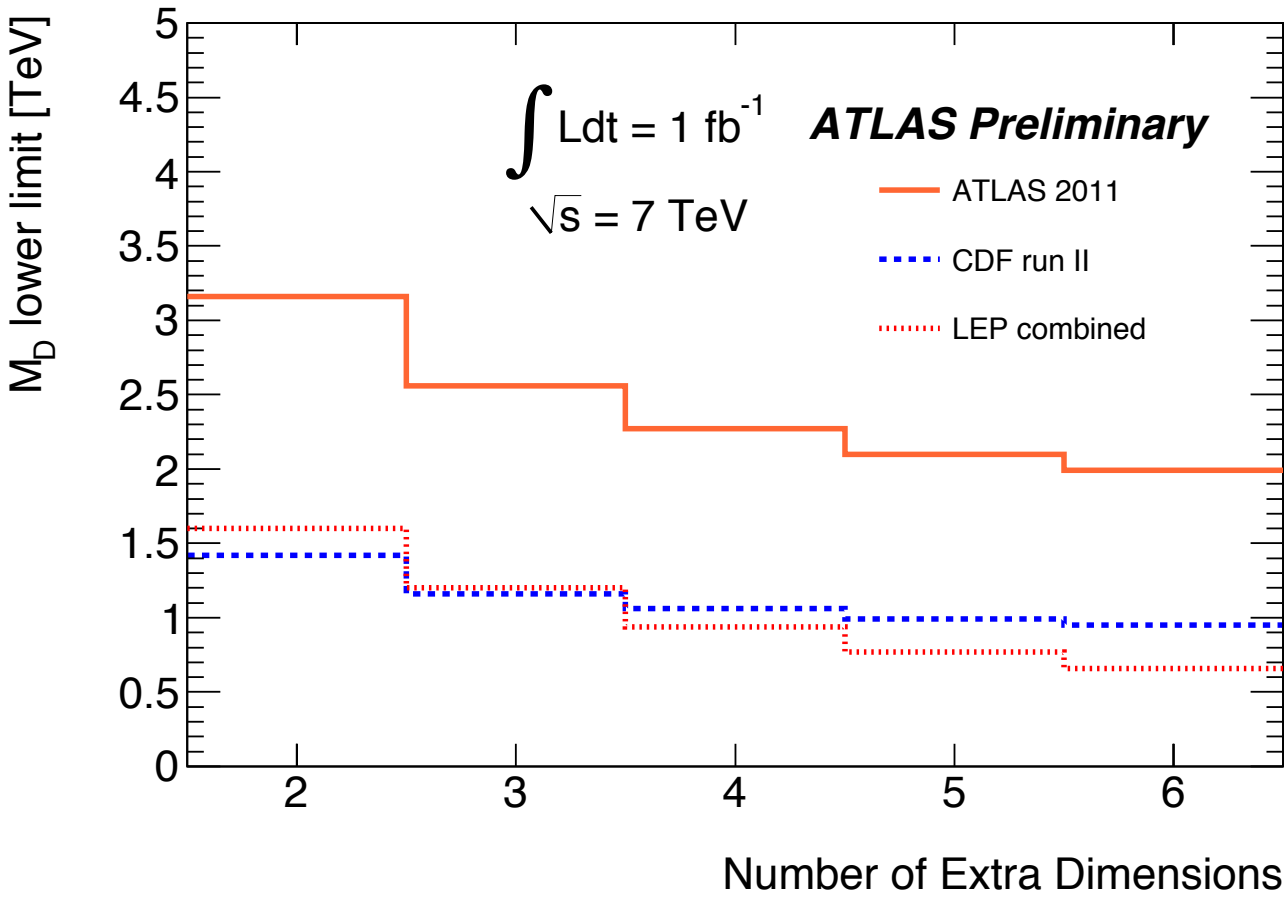


Results

	Background Predictions ± (stat.) ± (syst.)		
	LowPt Selection	HighPt Selection	veryHighPt selection
$Z(\to \nu\bar{\nu})$+jets	$7700 \pm 90 \pm 400$	$610 \pm 27 \pm 47$	$124 \pm 12 \pm 15$
$W(\to \tau\nu)$+jets	$3300 \pm 90 \pm 220$	$180 \pm 16 \pm 22$	$36 \pm 7 \pm 8$
$W(\to e\nu)$+jets	$1370 \pm 60 \pm 90$	$68 \pm 10 \pm 8$	$8 \pm 1 \pm 2$
$W(\to \mu\nu)$+jets	$1890 \pm 70 \pm 100$	$113 \pm 14 \pm 9$	$18 \pm 4 \pm 2$
Multi-jets	$360 \pm 20 \pm 290$	$30 \pm 6 \pm 11$	$3 \pm 2 \pm 2$
$Z/\gamma^*(\to \tau^+\tau^-)$+jets	$59 \pm 3 \pm 4$	$2.0 \pm 0.6 \pm 0.2$	-
$Z/\gamma^*(\to \mu^+\mu^-)$+jets	$45 \pm 3 \pm 2$	$2.0 \pm 0.6 \pm 0.1$	-
$t\bar{t}$	$17 \pm 1 \pm 3$	$1.7 \pm 0.3 \pm 0.3$	-
γ+jet	-	-	-
$Z/\gamma^*(\to e^+e^-)$+jets	-	-	-
Non-collision Background	$370 \pm 40 \pm 170$	$8.0 \pm 3.3 \pm 4.1$	$4.0 \pm 3.2 \pm 2.1$
Total Background	$15100 \pm 170 \pm 680$	$1010 \pm 37 \pm 65$	$193 \pm 15 \pm 20$
Events in Data (1.00 fb^{-1})	15740	965	167

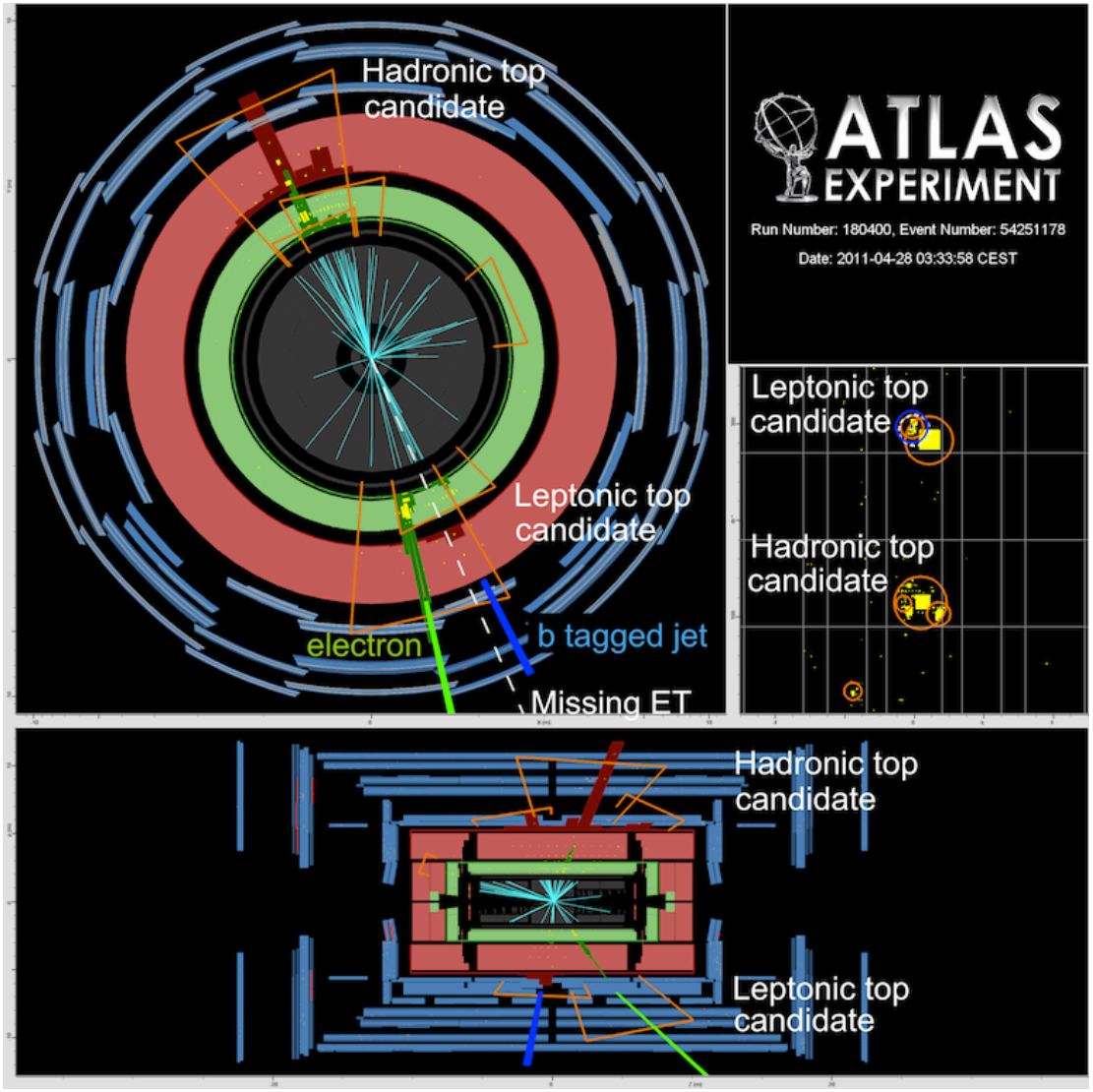
Data consistent with SM expectation within uncertainties.

Limits



M_D < 2 TeV excluded for ADD with n ≤ 6

Lepton + Jets



m_{tt} = 1602 GeV

ATLAS-CONF-2011-87

Backgrounds

- Irreducible background from SM ttbar production
- Additional background from W/Z+jets, QCD, single top, and Diboson
- All backgrounds estimated using MC prediction normalized to NLO cross section except W+jets (normalized to data) and QCD (entirely data-driven estimate)

Object Reconstruction

- Jets reconstructed using anti-k_T algorithm with cone size of 0.4
  - Jets within $\Delta R < 0.2$ of an electron are removed
  - SV0 algorithm used to find secondary vertices for b-tagging
- Electrons reconstructed using tight selection criteria and must have $p_T > 25$ GeV and $|\eta_{cal}| < 2.47$
  - Other requirements: E/p consistent with electron, $1.37 < |\eta_{cal}| < 1.52$, hit in innermost pixel layer (if live)
- Muons must be combined and have $p_T > 20$ GeV and $|\eta| < 2.5$

Lepton Isolation

- Leptons also required to be isolated
- For electrons E_T in cone w/ $\Delta R=0.2 < 4$ GeV
- For muons
  - E_T in cone w/ $\Delta R=0.3 < 2.5$ GeV
  - p_T in cone w/ $\Delta R=0.3 < 2.5$ GeV
  - $\Delta R > 0.4$ with any jet with $p_T > 20$ GeV

Event Selection

- Require exactly one isolated lepton and at least four jets with $p_T > 25$ GeV and $|\eta| < 2.5$, at least one of which must be b-tagged
- In electron channel, require MET > 35 GeV and M_T(lep,MET) > 25 GeV
- In muon channel, require MET > 20 GeV and M_T(lep,MET) > 60 GeV
- Also reject events where electron shares track with non-isolated muon

W+jets Normalization

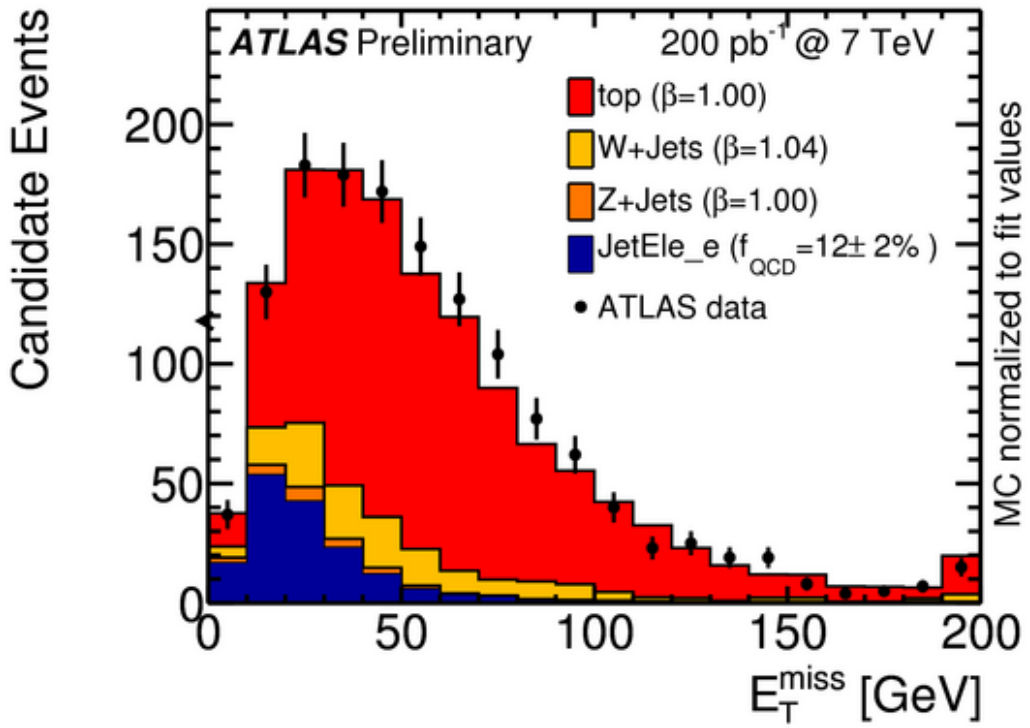
- Define control region by reversing b-tagging cut
- Require MET, M_T near W mass
- Subtract contributions from other SM processes using MC predictions
- Fit to jet multiplicity distribution

QCD Estimation

- Look for either jets with high EM fraction or electron candidates that fail hadronic leakage cut to model fake leptons or electrons
- Select events with no good leptons to get QCD enriched sample
- This provides a template for QCD events with a fake lepton

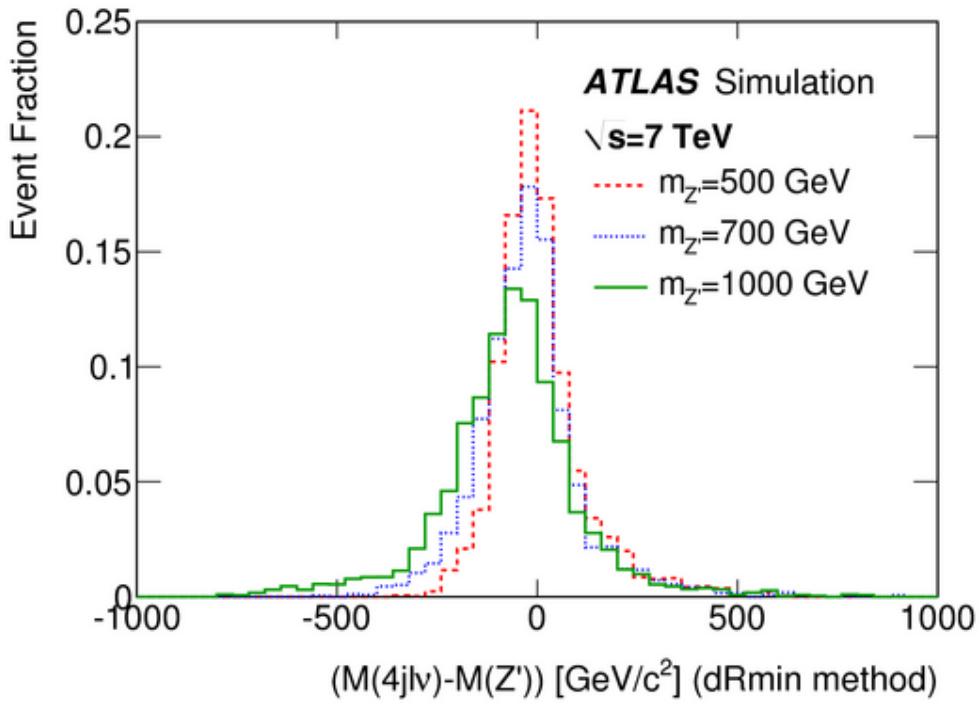
QCD Estimation

- Add template to predictions for other backgrounds and fit to MET spectrum



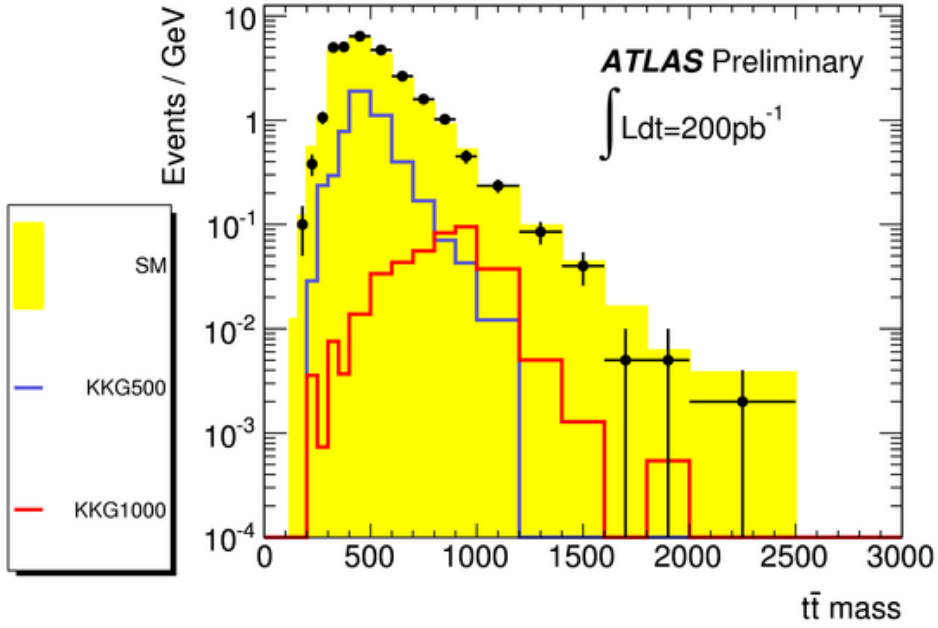
Ttbar mass reconstruction

- Fix neutrino p_z using W mass constraint
- Improve mass resolution by using dRmin algorithm to reduce use of jets from ISR/FSR
  - Rejects fourth jets that are far away ($\Delta R > 2.5 - 0.015 * m_j$) from the lepton and other jets



Results

	Electron channel	Muon channel
$t\bar{t}$	724	988
Single top	36	50
W+jets	93	172
Z+jets	6	8
Diboson	2	2
Total MC Background	861	1220
QCD Background	35	105
Total Expected	896	1325
Data observed	935	1396
Z', m = 500 GeV	15	21
g_{KK}, m = 700 GeV	68	93



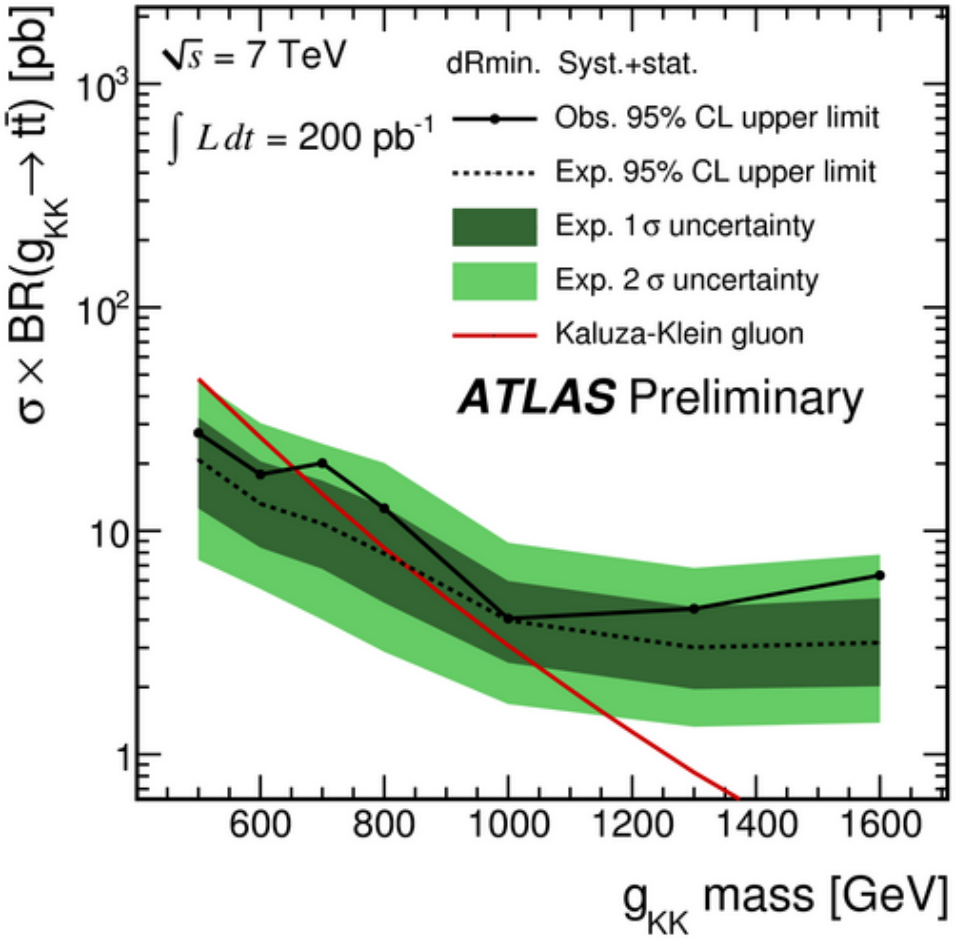
Data agrees well with SM prediction in both shape and overall rate.

Systematics

Luminosity	4.5%
Lepton Trigger/ID	≤ 1.5%
b-tagging eff.	11%
JES	9%
ISR/FSR	7%

Background Normalization	
ttbar	+7%/-9.6%
single top	10%
W+jets	35%
Diboson	5%
QCD(e)	30%
QCD(μ)	50%

Limits



Kaluza-Klein gluons with mass below 650 GeV are excluded.

Conclusions

- We are starting to have sensitivity to new physics from extra dimensions at the TeV scale.
- No evidence yet for the existence of extra dimensions.
- Many more collisions to study, so stay tuned…